ISCR-Enhanced Bioremediation Accelerates Groundwater Cleanup at Active Manufacturing Facility

Full-scale in situ chemical reduction (ISCR) was initiated in 2009 at the Siltronic Corporation site in Portland, OR, to treat a chlorinated solvent source area with TCE DNAPL. Implementation involved construction of a 150-foot-long permeable reactive barrier (PRB) containing a controlled-release, integrated carbon and micro-scale zero valent iron (ZVI) reagent and selected microbial agents in the source zone. ISCR-enhanced bioremediation was selected due to its: (1) relatively low cost when compared to alternate but resource-intensive technologies such as electrical resistance heating; (2) higher predictability than technologies such as surfactant flushing or emulsified oil sequestration; and (3) compatibility with ongoing operation of an onsite manufacturing facility. The groundwater RAO set by the Oregon Department of Environmental Quality (ODEQ) was achieved within six months after PRB construction, and TCE concentrations further decreased to below the MCL in several onsite locations.

Silicon wafers have been manufactured at the 80-acre Siltronic site since 1980. Solvent releases during the 1980s created a TCE plume approximately 800 feet long and 200 feet wide, which discharges under and into the Willamette River. In 2006 site investigations, TCE was identified in source zone groundwater at concentrations that reached 592,000 µg/L, suggesting the presence of DNAPL. Investigations also indicated a TCE source zone approximately 40-110 feet bgs. ODEQ established a groundwater RAO for this removal action of reducing dissolved-phase TCE to less than 11,000 µg/L in source zone (Group 1) wells, the 1% TCE solubility commonly used to indicate presence of DNAPL.

Siltronic Corporation evaluated cleanup options given the limited space to operate and proposed a controlled-release mixture of carbon and ZVI that yields redox potentials (Eh) in the -500 to -650 mV range, a highly favorable range for the biological reductive dechlorination of contaminants. Although the presence of 1,2-DCE and vinyl chloride (VC) in groundwater indicated that natural biodegradation was occurring, Siltronic proposed augmenting the source area's microbial populations with specific TCE-targeting microbes and stimulating existing populations with an additional carbon source. The resulting increase in microbial activity was expected to induce an increased gradient leading to DNAPL dissolution and microbial destruction of contaminants. The additional presence of ZVI was expected to contribute to contaminant removal through abiotic reduction and provide a long-lived (14 to 21 years) mechanism for addressing potential rebound caused by contaminants desorbing from the soil matrix.

Starting in January 2009, a 30% carbon and ZVI slurry was injected at depths of 40-112 feet bgs using a direct push (DP) drill rig with a tailored injection head. The slurry was injected on the downward push of the injection head to target 4-foot vertical intervals among injection point lines at 7-foot spacing. The microbe culture was emplaced 7-14 days later in the same holes through use of a peristaltic pump and a standard DP well screen deployed in a bottom-up fashion. This injection process continued for six months emplacing approximately 200 overlapping injection points along a 150-foot line serving as the source zone PRB. Based on material volumes used in an earlier pilot-scale field test, approximately 594,000 pounds of the carbon and ZVI fine powder and 1,831 liters of microbe culture were injected into the subsurface.

Onsite groundwater was monitored monthly at 23 (note: to date, only Group 1 and Group 2 wells have affected by EIB treatment. This represents 12 of the 23 wells cited.) wells located upgradient, within, and downgradient of the PRB. Through December 2009, TCE concentrations in all the wells had decreased to levels significantly lower than the 11,000 µg/L goal. Concentrations had dropped to less than 100 µg/L at 21 wells and to less than the 5 µg/L MCL in 11 wells (some of these wells were below 5 ug/l before treatment began). The lack of sustained increases in TCE daughter products downgradient of the injection zones suggested that mass destruction of TCE and its degradation products occurred both within and downgradient of the injection zones (This may be a valid statement for Group 1 and Group 2 wells (source area) but does not apply to Group 3 riverfront wells – treated water has not arrived at these wells yet) . A comparison of decreased TCE concentrations versus increased DCE and chloride concentrations provided evidence of abiotic reductive dehalogenation. Downgradient sampling in 11 additional onsite wells showed similar results (Figure 3) (As indicated below, Figure 3 is not relevant to EIB performance).

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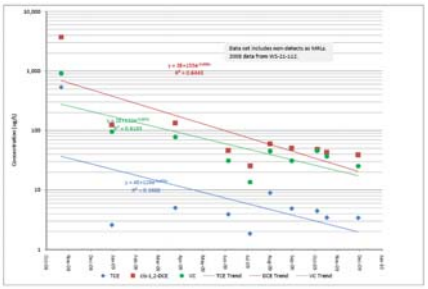

Figure 3. TCE, DCE, and VC geometric mean concentration trends of 11 monitoring wells x-x feet downgradient of the Siltronic PRB suggest simultaneous abiotic degradation and biological reduction. The above figure should not be included in the article. It displays data from Group 3 wells, which as previously noted, have not been affected by EIB treatment – the advective front has not arrived at these wells yet. The downward trend line is primarily an artifact of which wells were used in the analysis over time (i.e. the 2008 data represent 1 well, 2009 data represent 11 wells. As an alternative, I would suggest a graph displaying data from Group 1 and Group 2 wells, which do show remarkable reductions. We have also been critical of their application of the geometric means and how they have been used to interpret trends. We are requiring Siltronic to use mass flux and prediction limits for performance monitoring instead of the geometric means they have used previously.

Data indicated that chloride was generated approximately seven times faster than the rate of TCE destruction; the excess chloride in the dissolved phase indicated that excess TCE mass existed, likely as DNAPL (We haven't thoroughly reviewed this data set, but it appears to be a reasonable conclusion). Geostatistical modeling suggested that 98% of the estimated pre-treatment TCE mass (250 kg) (This value came from an early estimate of TCE mass, and likely substantially underestimates true mass that was present prior to EIB treatment, I believe Siltronic would concur.) was reduced due to ISCR-enhanced bioremediation. Modeling also showed that field data are consistent with an expected TCE half-life of 10-30 days (independent of starting concentration), which supported the conclusion that degradation of TCE DNAPL had followed a first-order reaction characteristic of both abiotic and biologically-mediated pathways.

Project costs totaled approximately $xxx, including costs for the injected materials. Unit costs averaged $x/lb for the carbon and ZVI and $x/L (I asked James Peale about costs, he discussing with his client to see if they will release the information. for microbial augmentation. Overall results suggest that injection of lower material volumes could have yielded similar results.

Source-zone monitoring will continue [how long?] (we haven't and are not likely to specify a period at this time, this was a removal action and we have not established final cleanup concentrations)as cleanup progresses for other onsite contamination, such as petroleum byproducts released from adjacent properties in the past. Destruction of the DNAPL source zone is expected to reduce contaminant loading to the adjacent Willamette River and facilitate natural attenuation of remaining VOCs.

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